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Original Research

Analysis of the Nutrient Foramen in Human Dry Ulnae of Turkish Population: An Anatomical Study and Current Literature Review

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ABSTRACT

Objective: The nutrient artery which enters through the nutrient foramen (NF) provides blood circulation and nutrition in long bones. This supply is essential during the growing period, the early phases of ossification, and in some surgical procedures. This study aimed to investigate NF in adult human ulnas in the Turkish population.

Methods: For this study, 155 (70 right and 85 left) Turkish dry adult human ulnas were used. The presence, number, and patency of NF were recorded as well as its topography and direction. The vertical distance between the most proximal point of the olecranon and the proximal edge of the NF (DONF), and the longitudinal distance between the most ventral point of the coronoid process on the sagittal plane and the proximal edge of the NF (DCpNF) was calculated. Additionally, the foraminal index (FI) was assessed.

Results: Single and double NFs were in 139 ulnas (89.67%), and 3 ulnas (1.94%), respectively. NFs were not observed in 13 ulnas (8.39%). The majority of NFs (93.12%) were situated on the anterior surface of the ulna. The direction of all NFs was towards the elbow. The mean DONF and DCpNF were 9.48 ± 1.57 cm, and 6.68 ± 1.44 cm, respectively. The FI was 37.45% in ulnas with a single NF, while it was 41.46% in ulnas with a double NF.

Conclusion: Our study has presented additional information such as the FI of ulnas with 2 NFs, and the distance between the coronoid process and NF in the Turkish population.

Keywords: Nutrient foramen, ulna, clinical importance, foraminal index.

INTRODUCTION

The long bone is supplied by a nutrient artery, which enters the bone obliquely through the nutrient foramen (NF), which is directed away, as a rule, from the growing end [1]. The nutrient artery is the principal source of blood supply to a long bone and is particularly important during its active growth period in the embryo and fetus, as well as during the early phase of ossification [2, 3]. During childhood, the nutrient arteries provide 70–80% of the interosseous blood supply to long bones: when this supply is compromised, medullary bone ischemia occurs with the metaphysis and growth plate both becoming less vascularized [1, 3, 4]. An understanding of the location and number of nutrient foramina in long bones is, therefore important in orthopedic surgical procedures such as joint replacement therapy, fracture repair, bone grafts and vascularized bone microsurgery, as well as in medicolegal cases [2]. Topographical knowledge of these nutrient foramina is useful in operative procedures to preserve circulation [1]. When a bone graft is taken, the vascularization of the remaining bones has to be considered [1]. The vascularity of this area allows various options in grafting [1]. It was reported that the ideal bone graft for free transfer should include endosteal and periosteal blood supply with good anastomosis [2]. Moreover, the presence of preserved nutrient blood flow is essential for the survival of osteocytes in cases of tumor resection, traumas, and congenital pseudoarthrosis [4]. However, there is still a need for a greater understanding of nutrient foramina in bones [5]. The goal of the present study was to investigate the number, position and direction of the nutrient foramen in adult human ulnas in Turkish population.

METHODS

This study was conducted on 155 (70 right and 85 left) Turkish dry adult human ulnas, whose ages and gender were not recorded in the İstanbul University, Faculty of Medicine, Department of

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Anatomy. All bones included in the study were normal bones without any pathological findings. Ethical approval was granted by the Clinical Research Ethical Committee of İstanbul University Faculty of Medicine (IRB Date: 25/06/2021, Number: 13].

Nutrient foramen (NF) was investigated and the following parameters related to NF were examined.

1. The number of NFs was macroscopically observed in each bone.
2. The patency and direction of the NF were determined by an acupuncture needle with dimensions of 0.25 X 30 mm. Foramen smaller than the size of the needle were not analysed or reported in this study.
3. The topography of the foramen in specific borders or surfaces of the bone body was analysed with the naked eye.
4. The vertical distance between the most proximal point of the olecranon and proximal edge of the NF (DONF) was determined (Figure 1 A).
5. The longitudinal distance between the most ventral point of the coronoid process on the sagittal plane and the proximal edge of the NF (DCpNF) was measured (Figure 1 B).
6. The total length of ulna (TL) was measured as the vertical distance between the most proximal point of the olecranon and styloid process (Figure 1 C).

Additionally, the foraminal index (FI) was calculated by using the following formula: FI = (DONF/TL) X 100 (6).
The position of the foramen according to FI was divided into 3 types according to the following limits:
Type 1: FI below 33.33%, proximal third of the ulna.
Type 2: FI between 33.33% and 66.66%, middle third of the ulna.
Type 3: FI above 66.66, distal third of the ulna.

The measurements were made by two independent researchers, and the mean value per parameter was written down as the final value. A digital caliper accurate to 0.01 mm (INSIZE Co., Ltd., Taiwan) was used for distances. In ulnas with 2 NF, DONF, DCpNF and FI values were measured separately for each foramen.

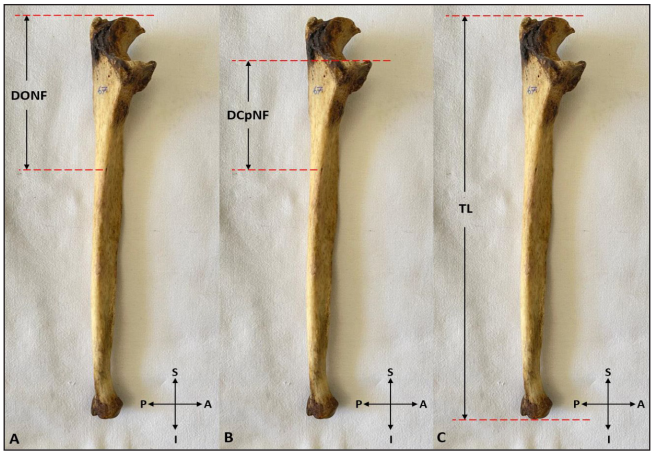

Figure 1. A-C. Main elements measured on the ulna. DONF: distance of olecranon-nutrient foramen. DCpNF: distance of coronoid process-nutrient foramen. TL: total length of ulna. S: superior. I: inferior. P: posterior. A: anterior.

RESULTS

In the current study, 155 ulnas were examined. Single NFs were detected in 89.67% (139 ulnas) (Figure 2 A) and double NFs in 1.94% (3 ulnas) of the bones (Figure 2 B), however, NFs were not found in 8.39% (13 ulnas) of the bones. The direction of all nutrient foramina was towards the elbow (Figure 3). Table 1 summarizes the side and number of nutrient foramina.

The majority of NFs (93.12%, 135 NFs) were situated on the anterior surface of the ulna (Figure 4 A), whereas the remaining were on the anterior border and interosseous border at equal rates (3.44%, 5 NF) (Figure 4 B-C). Table 2 summarizes the topography of the NFs.

The total length of ulna (TL) was as a mean of 25.88 ± 3.79 cm and the distance between the most proximal point of the olecranon and proximal edge of the NF (DONF) was a mean of 9.48 ± 1.57 cm.

The DCpNF was calculated as a mean of 6.68 ± 1.44 cm in 139 ulnas with a single NF, while it was a mean of 6.77 ± 1.64 cm in 6 ulnas with a double NF. The mean FI was 37.45% in ulnas with 1 NF and 41.46% in ulnas with 2 NF. Additionally, 22.75% of NFs were type 1, and 77.25% of NFs were type 2. Table 3 summarizes the FI of the NFs.

Figure 2. A. Showing single NF on ulna. **B.** Showing double NF on ulna. NF: nutrient foramen. S: superior. I: inferior. M: medial L: lateral.

Figure 3. A-D. Photographs of showing NF directed proximally. S: superior. I: inferior. M: medial. L: lateral. P: posterior. A: anterior.

Figure 4. A. Ulna with NF on the anterior surface. **B.** Ulna with NF on the anterior border. **C.** Ulna with NF on the interosseus border. NF: nutrient foramen. AS: anterior surface. AB: anterior border. IB: interosseus border. S: superior. I: inferior. M: medial. L: lateral. P: posterior. A: anterior.

Table 1. Side and number of the nutrient foramen of ulna

Number of NF	Right	Left	Total
	N (%)	N (%)	N (%)
0	3 (4.29%)	10 (11.77%)	13 (8.39%)
1	64 (91.42%)	75 (88.23%)	139 (89.67%)
2	3 (4.29%)	0	3 (1.94%)
Total	70 (100%)	85 (100%)	155 (100%)

NF: Nutrient foramen

Table 2. The topography of nutrient foramen

Location of nutrient foramen	Right	Left	Total
	N (%)	N (%)	N (%)
AS	66 (93.76%)	69 (92%)	135 (93.12%)
AB	2 (3.12%)	3 (4%)	5 (3.44%)
IB	2 (3.12%)	3 (4%)	5 (3.44%)
Total	64 (100%)	75 (100%)	145 (100%)

AS: Anterior Surface, AB: Anterior Border, IB: Interosseous Border

Table 3. Classification of nutrient foramen on the basis of foraminal index

FI	The number of NF		
	Right (n=70)	Left (n=75)	Total (n=145)
Type I (<33.33%)	16 (22.85%)	17 (22.66%)	33 (22.76%)
Type II (33.33%-66.66%)	54 (77.15%)	58 (77.34%)	112 (77.24%)
Type III (> 66.66%)	-	-	-

FI: Foraminal Index, NF: Nutrient foramen

DISCUSSION

This study investigated the number, position, and direction of NF and measured the mean distance between the coronoid process and NF. Similarly, the current paper indicated the mean FI in ulnas that had double NF.

The number of nutrient foramina

Although studies in the literature have shown that NF is mostly single, investigations in which NF is absent or double have also been reported. Parmar et al. [5] reported that the total number of ulna was 60, all of which had a single NF. Subsequent studies (Mishra et al., Charan et al., Uzuner et al.) [7, 8, 9] highlighted similar results as well. In their studies on adult human long bones of the upper and lower limbs, Kizilkanat et al. [2] observed that 101 ulnas (99%) had one NF and 1 ulna (1%) had two NFs. Pereira et al. [10] documented similar results to the findings of Kizilkanat et al. [2]. In the next three studies [1, 11, 12], the number of single foramina was obtained at a lower rate, however, the number of double foramina was found at a relatively higher rate. Solanke et al. [13] indicated that 96.25% (77 ulnas) of specimens had a single NF and 3.75% (3 ulnas) had no NF. A study conducted by Chavda et al. [14] showed that 96.67% of the ulna (145 ulnas) had a single nutrient foramen, 1.33% (2 ulnas) had a double foramen and 2% (3 ulnas) had no nutrient foramen. Additionally, in their study, Kumari et al. [15] noted that 3% (3 ulnas) did not have NF, 92% (92 ulnas) had a single foramen and 5% (5 ulnas) had double NF. On the other hand, Rangasubhe and Havaldar [16] assessed 100 ulnas and reported that 86 (86%) of them had a single NF, 13 (13%) had a double NF and 1 (1%) had three NFs. In the present paper, 89.67% (139 ulnas) had a single NF, 1.94% (3 ulnas) had a double NF, and 8.39% [13] of ulnas had no NF. Our single NF results are closer to the results of Kumari et al. [15] and the double NF results of this study are compatible with the findings of Chavda et al. [14]. Nevertheless, our results of the absence of NF are not consistent with the results of previous studies, and this inconsistency may be due to the difference in sample size and ethnicity. Because the nutrient artery is the main source of blood supply to the bone, it plays an essential role in fracture healing. Therefore, it may be important for surgeons to know the number of NF to protect the nutrient artery. At the same time, the number of ulna without NF in our study was higher than that in studies in the literature. Accordingly, preoperative planning may need to be modified according to this result. Azizi and Danish [1] highlighted that the NF may be a potential region of weakness in some patients and, under stress due to increased physical activity or decreased quality of the bone, the foramen may allow the development of a fracture. In our study, double NFs were found in 1.94% (3 ulnas) of the bones. According to the results of our study, we think that the probability of developing the fracture mentioned by Azizi and Danish (1) may be relatively high.

Direction and topography of the nutrient foramen

Most of the previous studies reached a consensus that the opening of the NF is towards the elbow. Nevertheless, Rangasubhe and Havaldar [16] observed 115 NF in their study and reported that 97% of NF were directed upper oblique, 2% lower oblique and remaining horizontally. Similar to the previous studies, the direction of all NF in the present study was also towards the elbow.

In the majority of studies in the literature, it has been reported that NF has the highest rate on the anterior surface, followed by the anterior border and interosseous border. A few studies have noted that NF can be found in the posterior surface or medial surface of the ulna [1, 11, 13, 16]. In the present study, NF was located on the anterior surface, anterior border, and interosseous border at 93.12% (135 NF), 3.44% (5 NF), and 3.44% (5 NF), respectively. Our results highly correspond with those of former studies.

Another topographical perspective of the NF of the ulna, the FI has been noted in the literature. Pereira et al. [10] found FI to be a minimum of 27.4% and a maximum of 52.5% and reported that the mean FI was 37.9%. Ukoha et al. [4] highlighted that the majority of NF (73%) were in the middle third (type 2) while 27% were in the proximal third (type 1) of the bone and recorded the mean FI was 36.70%. A study performed by Udayasree et al. [12] reported that the average FI was 34.91% and noted that 13.2% of NFs (5 NFs) were in the proximal third (type 1) of the ulna and 86.8% of NFs (33 NFs) were in the middle third (type 2) of ulna. Chavda et al. [14] stated that 63.76% of NFs were in the middle third (type 2) of the ulna, 22.15% were in the upper third of the ulna and 14.09% were in the lower third of the bones. They also mentioned that the mean FI was 35.34% [14]. Similar to the study of Ukoha et al. [4], Azizi and Danish [1] indicated that most of the NF (80%) were located in the middle third, while the remaining (20%) were situated in the upper third of the ulna. Likewise, Rangasubhe and Havaldar [16] determined that 85.22% of NFs were in the upper third and 12.17% were in the middle third of the ulna. Priya et al. [11] calculated that the mean FI was 35.83 ± 6.12 and reported that 40% of NF were present in the type 1 category and 60% in type 2. On the other hand, Kumari et al. [15] showed that the location of NF in relation to the length of the ulna was 25.4% in the upper 1/3rd, 62.7% in the middle 1/3rd, 11.76 % at the junction of the middle and upper 1/3rd, and no NF in the distal 1/3rd of the ulna.

In the current study, the mean FI was 37.45% in ulnas with 1 NF and 41.46% in ulnas with 2 NF. Moreover, 22.75% of NFs were type 1 and 77.25% of NFs were type 2. Our classification results of NF are very close to the classification results of NF that were reported by Azizi and Danish [1] and our mean FI results are consistent with previous studies. Knowing the direction and location of NF may help surgeons who study joint replacement therapy, fracture repair, bone grafts, and vascularized bone microsurgery. Thus, the success rate of applications might increase.

Distance between the coronoid process and NF (DCpNF)

In applications related to NF of the ulna, DCpNF was conducted to easily reach NF. In 139 ulnas with a single NF, the DCpNF was a mean of 6.68 ± 1.44 cm. Additionally, this value was obtained as a mean of 6.77 ± 1.64 cm in 6 ulnas with double NF. No similar study could be found that measured this distance before. Knowledge of the accurate location of NF may aid surgeons in preventing intraoperative injuries in orthopedic, plastic and reconstructive surgery [2]. In this sense, the mean DCpNF value may be a guide for surgeons.

Limitations

We did not reach the records of gender and age of ulnas. Analyzing the ulnas according to their gender and age could have expressed more meaningful results. Difficulties in knowing the characteristics of dry bones such as age, gender, or race have been reported in the literature [17].

CONCLUSION

Anatomy has traditionally been a reliable source of information for surgical operations. The outcomes of this study corroborated those of previous studies on ulnar NF. The current study has provided additional information on the foraminal index, morphology and topography of the nutrient foramina in ulna bones. Accurate knowledge of the position and number of the nutrient foramen of ulna could be important in orthopedic surgical procedures such as vascularized bone microsurgery, bone grafts, joint replacement therapy and fracture repair. The anatomical data of this subject are enlightening to the clinician to avoid damage to the nutrient vessels during surgical procedures and can be of use for review by orthopedic surgeons for planning surgeries in the region of the forearm.

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